Faculty of Mechanical Engineering

IMPROVEMENT OF AN INDOOR ENVIRONMENTAL QUALITY (IEQ) IN UNIVERSITY HEALTHCARE BUILDING

Mohd Syahrir Bin Mohd Shah

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IMPROVEMENT OF AN INDOOR ENVIRONMENTAL QUALITY (IEQ) IN UNIVERSITY HEALTHCARE BUILDING

MOHD SYAHRIR BIN MOHD SHAH

A thesis submitted
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DECLARATION

I declare that this thesis entitled "Improvement of an Indoor Environmental Quality (IEQ) in University Healthcare Building" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Mohd Syahrir Bin Mohd Shah

Date : 4/3/19

APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Master of Mechanical Engineering (Energy Engineering).

Signature : .....

Supervisor Name : Associate Professor Dr. Tee Boon Tuan

Date : 5 MARCH 2019

ABSTRACT

Indoor Environmental Quality (IEQ) is important to business, building managers, facilities staffs and employees of particular building because it can contribute both positive and negative impact to the health conditions, comfort feelings, wellbeing and productivity of the building occupants, including health care premises. The Indoor Air Quality (IAQ) is vital to be assessed within hospitals and other health care buildings. The patients and staffs within these establishments can be impacted directly by the quality of air in the building. The main objective of the study is to determine the indoor environment condition of university healthcare building. Physical measurement was conducted using Delta Ohm Thermal Microclimate, IAQ-Calc Indoor Air Quality Meter 7545 and DustTrack II Aerosol Monitor to analyse thermal comfort and indoor air quality as to evaluate the indoor environment quality of the indoor healthcare areas. Physical measurements were conducted with occupancy while subjective measurement was carried out through self-administered questionnaire surveys. Result shows that the indoor air temperature and air velocity not complied to MS 1525 standard. While, the concentration of PM10 inside the building also not complied to DOSH standard. The Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) not complied to ASHRAE standard. Based on the subjective measurement, only 26.3% feeling comfort while being inside the building. With regards to the findings, indoor environment quality (IEQ) improvement measures are proposed to enhance the IEQ level of the building. The study suggested that the temperature of the air conditioners should be set at 21°C with air velocity of 1,144.2 cfm, and the fresh air also must be supplied to the areas.

ABSTRAK

Kualiti persekitaran dalaman (IEQ) adalah penting untuk perniagaan, pengurus bangunan, penyewa, kakitangan fasiliti dan para pekerja bangunan tertentu kerana ia boleh memberi kesan positif dan negatif kepada keadaan kesihatan, keselesaan, kesejahteraan dan produktiviti penghuni bangunan, termasuk premis penjagaan kesihatan. Kualiti udara dalaman (IAQ) adalah sangat penting untuk dinilai di bangunan hospital dan penjagaan kesihatan yang lain. Pesakit dan kakitangan yang menjaga pesakit di dalam bangunan ini boleh mendapat kesan langsung kualiti udara di dalam bangunan. Objektif utama kajian ini adalah untuk menentukan keadaan persekitaran dalaman di bangunan penjagaan kesihatan universiti. Pengukuran fizikal dijalankan menggunakan Delta Ohm Thermal Microclimate, IAQ-Calc Indoor Air Quality Meter 7545 dan DustTrack II Aerosol Monitor untuk menganalisa keselesaan haba dan kualiti udara dalaman di kawasan kemudahan penjagaan kesihatan. Pengukuran fizikal dijalankan dengan keadaan bangunan berpenghuni sementara pengukuran subjektif dijalankan melalui soal selidik yang dikendalikan oleh penyelidik. Keputusan menunjukkan suhu udara dan halaju udara dalaman tidak mematuhi piawaian MS 1525. Sementara itu, kepekatan PM10 di dalam bangunan juga tidak mematuhi piawaian DOSH. Anggaran vot purata (PMV) dan anggaran peratusan ketidakpuasan (PPD) juga didapati tidak mematuhi piawaian ASHRAE. Berdasarkan kepada pengukuran subjektif, hanya 26.3% berasa selesa ketika berada di dalam bangunan tersebut. Berdasarkan hasil dapatan kajian, beberapa langkah penambahbaikan telah dicadangkan bagi meningkatkan lagi tahap kualiti persekitaran dalaman (IEQ) bangunan. Kajian ini mencadangkan agar suhu penghawa dingin ditetapkan pada suhu 21°C dengan halaju udara sekurang-kurangnya pada kadar 1,144.2 cfm, dan udara segar juga perlu dibekalkan di kawasan-kawasan tersebut.

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LIST OF SYMBOLS

°C	-	Degree Celsius
°F		Fahrenheit
m	-	Metre
mm	-	Millimetre
s	-	Seconds
%	-	Percent
W	-	Watt
m/s	-	Velocity
ppm	-	Parts-per-million
cfm	-	Cubic feet per
R2	-	minute
L/s	-	Coefficient of determination
		Litre per second

LIST OF ABBREVIATIONS

ABBREVIATION		DESCRIPTION
ACMV	-	Air-Conditioning and Mechanical Ventilation
AIA	-	American Institute of Architects
AOV	-	Air Odour Vote
ASHRAE	-	American Society of Heating, Refrigeration and Air-Conditioning Engineers
AV	-	Air Velocity
CEN	-	European Standardization Organization
CIRIA	-	Construction Industry Research and Information Association
CLO	-	Clothing Insulation Value
CO	-	Carbon Monoxide
CO_2	-	Carbon Dioxide
DOSH	-	Department of Occupational Safety and Healthy
EEL	-	Engineer Education Laboratories
EPA	-	Environment Protection Agency
EPBD	-	Energy Performance Building
HEPA	-	High-Efficiency Particulate Air
HVAC	-	Heating Ventilation Air-Conditioning
IAQ	-	Indoor Air Quality
IEQ	-	Indoor Environmental Quality
ISO	-	International Organization of Standardization
MS	-	Malaysia Standard
NO_2	-	Nitrogen Dioxide
PM	-	Particular Matter
PMV	-	Predicted Mean Vote
PPD	-	Predicted Percentage of Dissatisfied
RH	-	Relative Humidity
Rn	-	Radon

SA	-	United States of America
SBS	-	Sick Building Syndrome
SO_2	-	Sulphur Dioxide
USGBC	-	United States Green Building Council
UTeM	-	Universiti Teknikal Malaysia Melaka
VOC	-	Volatile Organic Compounds
WHO	-	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background

Indoor condition states of a building are one of the concerned issues as individuals generally invest a large portion of their energy inside the structures. The World Health Organization (WHO) stated that the indoor natural conditions significantly affect human healthiness. Health indoor air is perceived as a fundamental right. Individuals spend a substantial piece of their time every day inside such as in homes, workplaces, schools, medicinal services offices, or other private or open structures. The nature of the air they take in those structures is an essential determinant of their wellbeing and prosperity. The lacking control of indoor air quality subsequently makes a significant wellbeing load. Knowledge of indoor air quality, its wellbeing noteworthiness and the components that reason low quality are vital to empowering activity by significant partners, including building proprietors, designers, clients and tenants on the best approaches to maintain clean indoor air (WHO, 2009). Different researchers underline that awful indoor condition conditions will expand the danger of sick building syndrome (SBS) side effects, poor comfort fulfilment level and medical problems (Amin et. al, 2015).

Health premises like hospital and health care centre are basically and customarily a place for individuals to recuperate from sickness or malady, yet another idea requires such structures to offer more, especially following a few examinations which have exhibited that enhanced natural quality can build efficiency and diminish recuperation times (Giuli

et. al., 2013). Furthermore, weakness care indoor air quality (IAQ) may prompt medical clinic procured diseases, debilitated emergency clinic disorder and different word related dangers. Air-control measures are essential for decreasing spread of airborne organic particles in hospitals (Verde et. al., 2015).

Indoor environmental quality is essentially characterized by four factors, for example thermal comfort, air quality, lighting quality and acoustical quality. These variables are essential to be considered in design plan for new building. Nevertheless, indoor air quality and thermal comfort are the essential points to be considered and tended to by building designers. The indoor air quality is assessed by parameters which included carbon dioxide concentration, temperature and relative humidity (Talejko, 2017) while thermal comfort parameters incorporate air temperature, air velocity and relative humidity. In this exploration, the indoor air quality and thermal comfort will be the two fundamental concentrations in dissecting the indoor natural quality (IEQ) for university healthcare building. At the end of the analysis, effective ways will be prescribed to enhance the IEQ for the building.

1.2 Problem Statement

The campaign for good and cosy workplace in building has not yet flourished in the part of healthcare facilities. Green buildings have been connected more significance to the natural thought of the manufactured frame while wellbeing and occupants are given less consideration. Researchers are however, understanding the need to focus on economical tenant condition as a proportion of achieving practical improvement. Healthcare service and offices quality and execution can be improved where constant execution assessment of the healthcare condition is completed to take care of obvious issues. This study aims to provide healthcare owners, experts and the built environment expertise with applicable

data on the procedures engaged with the appraisal of indoor environmental quality and influence of the healthcare atmosphere on its residents.

It is important to conduct healthy indoor air quality (IAQ) monitoring activities at health care environment in order to ensure healthy indoor environment (El-Sharkawy and Noweir, 2014). Jung et. al. (2015) investigated the distributions of indoor air pollutants in different areas of hospitals and examine how they might be associated with various types of air conditioning systems. they found that environments equipped with central air conditioning systems appear to lower indoor aerosol but show no particular benefit for controlling indoor CO concentrations in hospitals. Further, it was suggested that future investigation should be designed to explore how different work areas and ventilation types could better manage indoor air quality, and therefore, benefit occupant health.

1.3 Objectives

The main objectives of this research are:

i. To conduct thermal comfort analysis and indoor air quality analysis for university healthcare building.

ii. To propose an effective Indoor Environment Quality (IEQ) improvement measures for the university healthcare building.

1.4 Scopes of The Study

In this study, thermal comfort and indoor air quality is the main focus and analysis are conducted in UTeM healthcare building. The areas of the building include in the analysis are (i) registration waiting area, (ii) pharmacy waiting area and (iii) administrative office. The thermal comfort parameters such as air temperature, air velocity and relative humidity will be measured by using thermal comfort meter. Indoor air quality parameters

such as carbon dioxide concentration and dust concentration will be measured by using IAQ meter and Dust Track meter. Subjective measurements are conducted through questionnaire survey in order to obtain occupants' perception towards the current indoor condition.

1.5 Preliminary Hypothesis

Preliminary investigation on UTeM's healthcare building condition found that the building was not designed according to normal standard. Result from that, expectation on indoor environmental quality especially on gas contamination and thermal comfort are poor. This study aims to provide healthcare owners, experts and the built environment expertise with applicable data on the procedures engaged with the appraisal of indoor environmental quality and influence of the healthcare atmosphere on its residents.

1.6 Significant of Study

This study aims to provide healthcare owners, experts and the built environment expertise with applicable data on the procedures engaged with the appraisal of indoor environmental quality and influence of the healthcare atmosphere on its residents. The data will be a benchmark for indoor environment analysis for healthcare building.

1.7 Project Planning

Basically, the activities to carry out the study took place in 15 weeks of the semester, commencing on the first week of September and finished by the end of December 2018. Appendix 1 provides the illustration on the project planning of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Healthcare Facility and Building

The physical environment of the healthcare centre is vital factor in the quality of health care and well-being, as therapeutic resource for good health then to sustenance for the attention and handling of patients. A healthcare atmosphere can be abstracted in both (i) bodily components such as space, distance, temperature, colour, and lighting, and the (ii) psychosocial component which connections with the people's interface and involvement of the atmosphere and their interactions with others in the environment. The good design in the healthcare services foundation is intricate in that it is a nexus for both generally unique ideas (for example style and climate) and even minded prerequisites (for example dispatching details and asset impediments), concurrently subject to the trends and opinions of what good design should be (Elf et. al., 2017).

In most premises or building standards, there are recommend conditions planned to encourage situations that are satisfactory to tenants. Indoor air quality and thermal comfort are two vital parts of indoor environmental quality that get significant consideration by building planners (MS 1525, 2014). The perplexing hospital condition and other healthcare service providers requires exceptional regard for guarantee great and good indoor air quality (IAQ) to ensure patients and social insurance specialists against emergency clinic gained contaminations and other word related sicknesses. Poor hospital IAQ may cause

episodes of building-related sickness, for example, cerebral pains, weariness, eye, and skin aggravations, and different manifestations (El-Sharkawy and Noweir, 2014)

2.2 Building Indoor Environment Quality (IEQ) Theory and Standard

Indoor Environment Quality (IEQ) is a term used to describe the condition inside a building or setting, which include the air quality, lighting, thermal conditions acoustics, ergonomics and effects on its occupants. It is a vital element in building design relevant to green design and human health outcomes, where, the aim of the IEQ primarily focus on providing a comfort environment and to reduce any building sickness potential (U.S. Green Building Council, 2014; Collinge, et. al., 2012; Blyussen, 2009).

In many building settings, people are continuously exposed to different indoor environment quality issues where mostly relate to particulate pollutants. As number of sick building related disease increase, a few organizations are working on predicting and identifying the contaminant movements in air and to find out how to minimize the total exposure and several guidelines of Building Indoor Environment Quality (IEQ) Standard were introduced (Holmberg & Li, 1998). Among leading countries providing IEQ standards and renowned across the globe are United States of America (USA) and Europe.

Whereas in European countries, the European Standardization Organization (CEN) responsible in giving guidelines and standards for IEQ. In a study conducted by Olesen, Seppanen & Boerstra (2006) on indoor environment criteria for energy performance building (EPBD), they outlined The European draft standard by European Standardization Organization (CEN), it indicates the parameters of effect as well as criteria for indoor condition and how they are utilized to meet the goal in the EPBD, given as follows:

i. Specifies the indoor condition parameters, which affect vitality execution of structures and indicates how to set up indoor ecological info parameters for the building framework plan and vitality execution estimations.

ii. Specifies strategies for long haul assessment of the acquired indoor condition as the consequence of computations or estimations.

iii. Specifies criteria for estimations, which might be utilized whenever required by assessment.

iv. Identify parameters to be utilized by observing and showing the indoor condition in existing structures.

v. Is material fundamentally in the non-mechanical structures where the criteria for indoor condition are set by human inhabitant and where the creation or process does not majorly affect indoor condition. The standard is consequently relevant to the accompanying building types: single family houses, flat structures, workplaces, instructive structures, medical clinics, inns and eateries, sports offices, discount and retail exchange benefit structures.

In the United States of America (USA), The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) is a global professional association seeking to advance heating, ventilation, air conditioning and refrigeration systems design and construction. The organization is dedicated in promoting a sustainable world through a good IEQ practices. As the year 2018, ASHRAE serve more than 56,000 members from over 132 nations in providing standards and guidelines to achieve IEQ (ASHRAE, 2018).

Meanwhile, the most widely used and a globally recognized sustainable building rating system in the world is known as Leadership in Energy and Environmental Design (LEED). It is governing by the U.S. Green Building Council, aims to provide a framework to create healthy, highly efficient and cost-saving green buildings. The IEQ is considered as one of the vital components in achieving a proud sustainability achievement and recognition of LEED (U.S. Green Building Council (2018).

2.2.1 Malaysia Standard and Practice

Like other Western and European countries, Malaysia also poses its own standard with regard to indoor environment quality. Malaysia Standards MS 1525: 2014 is a code of practice related to the energy efficiency and use of renewable energy for non-residential buildings issued by Department of Standards Malaysia.

MS 1525: 2014 outlined that the comfort condition inside a building is depending on factors such as air temperature, air movement, humidity, clothing insulation and metabolic rate. To be specific, there are three main focus in an engineering design concerning on room comfort condition – dry bulb temperature, humidity and air movement. The indoor design for comfort cooling in air-conditioned space are as the following table.

Table 2.2.1 Indoor comfort condition measurement (MS 1525: 2014)

Item	Condition
Recommended design dry bulb temperature	24°C - 26°C
Minimum dry bulb temperature	23°C
Recommended design relative humidity	50% - 70 %
Recommended air movement	0.15 m/s – 0.50 m/s
Maximum air movement	0.7 m/s